VARIATIONS IN POPULATIONS AND CELL DIMENSIONS OF PHYTOPLANKTON IN THE ISLAND REGION OF WESTERN LAKE ERIE[1]

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During the fall of 1952 and the winter of 1953 water samples were taken around the Island region of Western Lake Erie in an effort to determine the phytoplankton populations in that region. In the fall of 1953 and the winter of 1954 samples were taken at a single station to supplement the data of the previous year. Three-dimensional measurements of each species of organism were made, and the populations were calculated in volumetric units.

AREA STUDIED

Samples during the years 1952–53 were taken along a triangular course, having a perimeter of about 60 miles, north of South Bass Island in Western Lake Erie. All sampling during this period was done within the following: longitude 41° 40′N and 41°50′N; latitude 83°00′W and 81°25′W (fig. 1). During the fall of 1953 and the spring of 1954 all samples were taken from the State of Ohio Fish Hatchery dock in Fishery Bay of South Bass Island.

METHODS

The sampling methods employed were those described by Verduin (1951a). The samples were taken weekly at approximately 10-mile intervals. At each sampling stop a bucket was filled and one liter of this water was strained through a small disc of number 25 silk bolting cloth with an aperture size of .064 mm. The filtered material was then resuspended by washing in a measured amount of filtered water, usually 10 or 20 ml., depending upon the density of the sample.

The samples taken in this study were from the surface only. Studies by Chandler (1940) indicate that the vertical distribution of the phytoplankton is essentially uniform. The data from 42 depth series taken during 1949 also showed no consistent trend with depth (Verduin, 1951a).

The counting was done with a Sedgewick-Rafter cell and a Whipple ocular micrometer (Welch, 1948). When ten fields had been counted and an average number of organisms per field had been determined, the volumes of the organisms were calculated by making (under 430X magnification) usually ten measurements of each dimension. When the average cell dimensions were found, the cell volume was calculated on the basis of the shape of the cell, the shapes in most cases being spherical, cylindrical, or a rectangular box. Both the average number of organisms per $mm.^3$ and the average volumes of their respective cells being known, it was possible to calculate the volume of phytoplankton per liter of lake water.

In the winter of 1954 it came to the writer's attention that some organisms might be escaping through the bolting cloth disc. To check this supposition 25 ml. of the filtrate was passed through an M. F. millipore filter (Lovell Chemical Co., Watertown, Mass.). This instrument, designed for bacteriological analysis of water, retains all particles greater than approximately 0.5 μ (Goldberg, 1952). The filtered material was counted and a significant loss of *Cyclotella melosiroides* (Kirsh.) Lemmerman from the bolting cloth disc was discovered. In subsequent collections a count was always made with the millipore filter, and the calculated volume was added to that obtained with the use of the bolting cloth. Organisms other than *C. melosirodies* occasionally passed through the bolting cloth, but the amounts were insignificant when total populations were considered.

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[1]From a thesis presented in partial fulfillment of the degree Master of Science, The Ohio State University, 1954.

The counts and measurements were made with an accuracy of 85 percent or better. Whipple (1927) states that when the Sedgewick-Rafter method is employed, two examinations of the same sample seldom differ by more than 10 percent. Serfling (1949) also found this to be true. Burkholder (1929) in his studies of Lake Erie found his error in counting diatoms to be about 18 percent. It is possible that an error may be introduced in the volumetric estimations as the phytoplankton cells are not always perfect cylinders, spheres, or rectangular boxes. The error attributable to this factor, however, is small; *i. e.*, if one were to assume that a rectangular box 10 μ x 10 μ x 100 μ were a cylinder 10 μ x 100 μ the volume obtained from this approximation would be about 22 percent too small. The geometric figures usually represent a better fit than in this hypothetical example.

The following references were used in identifying the organisms: Pestalozzi (1942), Smith (1933), Needham (1927), and Tiffany and Britton (1952).

RESULTS AND DISCUSSION

The bulk of the phytoplankton populations in Western Lake Erie in the fall, winter, and spring seasons are members of the Bacillariophyceae. The writer has no data showing what the major components were during the summer months; however, studies by Chandler (1940) show an increase in green and blue-green algae during this period.

The results of this study are presented as two separate groups of data: those samples taken over a wide range of territory and those taken at a single station.

The major components during the years 1952–53 are as follows: *Melosira* sp., *Asterionella formosa*, *Fragellaria* sp., *Cyclotella melosiroides*, *Tabellaria floculosa*, and *T. fenestrata* var *asterionelloides*. In the early fall and late spring, a green alga, *Pediastrum*, also appeared in significant numbers (averaging more than 1 percent of the populations during the fall months). Those found in insignificant numbers included *Aphanizomenon* sp., *Binuclearia* sp., *Anabeana* sp., *Polycystis* sp., and *Stephanodiscus* sp.

Two main types of communities were dominant throughout the year. *Asterionella-Melosira* made up the bulk of the populations during the fall and winter of 1952. In the spring of 1953, *Tabellaria* replaced *Melosira* as a major component, and there was also a significant amount of *Cyclotella*. During this season, *Tabellaria* made up approximately 42 percent of the total populations while *Asterionella* accounted for about 22 percent and *Cyclotella* and *Melosira* each made about 17 percent of the total.

Asterionella formosa Hass. was found as a co-dominant during all three seasons. On a yearly basis, therefore, it should be considered the major component. It is apparent that this diatom thrives under a wide range of physical conditions. Lund (1938) found it to have a temperature range of about 1.5° to 24°C.

It was stated earlier that significant amounts of *Cyclotella melosiroides* escaped through the bolting cloth. In the spring of 1954, it was found that from 45 percent to 79 percent of the total *C. melosiroides* population escaped. Since the cell size of this species was about the same in 1953 as in 1954 similar amounts were probably being lost that year. It must be kept in mind, therefore, that all stated figures of *Cyclotella* populations which were computed prior to March of 1954 may be considerably below the correct amounts.

Figure 1 shows average total populations during the fall sampling trips of 1952. The numbers shown are $\mu^3/1 \times 10^{-8}$ and are averaged from samples taken within an area of approximately 100 square miles. *Melosira* made up from 80 to 90 percent of the total populations with *Asterionella* and *Pediastrum* making up the difference. Figure 1 shows the relative positions of these populations, the largest being found to the north and east of Pelee Island. A similar map of the spring, 1953, collections indicated relatively uniform populations throughout the island area.

Wright and Tidd (1933), who made a limnological investigation of Western Lake Erie in 1929–30, reported large and highly consistent inequalities in horizontal distribution of phytoplankton in Western Lake Erie as a whole. Their area was much larger, including Maumee Bay, and the waters near the mouth of the Detroit River.

Qualitatively speaking it was found that, from the standpoint of horizontal distribution, the differences in species composition were negligible. The types of phytoplankton taken at a single station in 1953–54 may therefore be considered representative of the species occurring at the other stations during the same period.

During 1953, the fall community paralleled that of 1952 as to quality; *Melosira* making up some 95 percent of the total populations until late December. In the winter and spring of 1954, however, *Cyclotella* was much more abundant making up from 75 percent to 95 percent of the total populations. The single

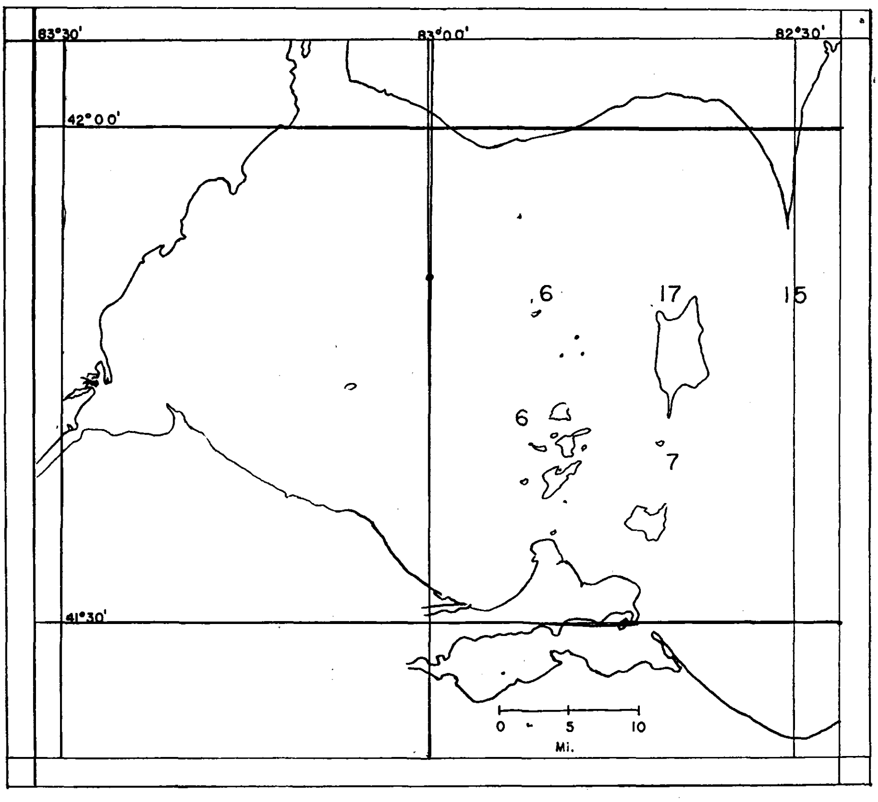

FIGURE 1. Map of Western Lake Erie showing horizontal distribution of phytoplankton populations during the fall of 1952. P identifies Pelee Island. Numbers represent μ^3 per liter ($\times 10^{-8}$).

station data for the two-year period are shown in figure 2. The population peak in 1952–53 came somewhat earlier than that in 1953–54; in the former season the maximal populations were found during January and February, while in the latter season the maximum was reached in April. The fact that the 1953–54 figures of *Cyclotella* populations were so much larger may be attributed to the introduction of the millipore filter in March of 1954.

A comparison of the populations calculated in this study and those found by Chandler (1940, 1942, 1944), Verduin (1951a, 1951b), and Curl (1950) is presented in table 1. Such comparison of data requires a number of explanations:

TABLE 1

Comparisons of Phytoplankton Data

Genus	1938-39[a]	1940[a]	1941[a]	1942[a]	1949[b]	1950	1951[c]	1952–53	1953–54
Asterionella	13.0 (Mar.)	9.4 (May)	70.0 (April)	32.8 (Mar.)	6.0 (April)	35.0[b] (May)	1.7 (Mar.)	6.5 (Feb.)	4.9 (Feb.)
Tabellaria	1.9 (Mar.)	8.4 (May)	2.1 (April)	59.1 (April)	200.0 (April)	NR	3.5 (May)	15.2 (May)	9.3 (Mar.)
Melosira	17.0 (Sept.	71.4 (Nov.)	32.9 (Oct.	59.1 (Sept.	NR	109.5[c] (Oct.)	1.80 (May)	41.0 (Sept.	9.7 (Dec.)
Cyclotella Melosiroides	NR	NR	NR	NR	NR	35.0[b] (May)	.75 (April)	40.5 (Feb.)	90.0 (April)
Stephanodiscus	50.2 (Oct.)	6.8 (Sept.)	2.8 (Sept.-Dec.)	2.8 (Sept.)	35.0 (May)	NR	NR	12.7 (Mar.)	.38 (Oct.)

Month maximum occurred is in parentheses
All values are x $10^8\mu^3$/liter
NR: not reported
a: data of Chandler (1938–1942) (reported in μ^3 as determined by this study)
b: data of Verduin (1949)
c: data of Curl (unpubl. MS Thesis, Ohio State Univ.)

1) all data of Chandler have been converted to units described in this paper on the basis of average cell sizes as determined here. Chandler arbitrarily accounted for variations in cell sizes by enumerating plankters as units per liter, the number of cells in a unit being dependent upon the size of the species. Thus eight cells of *Asterionella* or eight cells of *Tabellaria* were given equal weight with one cell of *Stephanodiscus*. The volume of one cell of *Asterionella*, however, was found, in the present study, to approximate 1000 μ^3, while one cell of *Stephanodiscus* varied between 16,000 and 20,000 μ^3. Eight cells of *Tabellaria*, on the other hand, were found to have a volume of from 20,000 to 30,000 μ^3. Conversion of Chandler's data, therefore, brought higher values than those indicated on his graphs. 2) Chandler found a species of *Cyclotella* similar in size to *Stephanodiscus*,

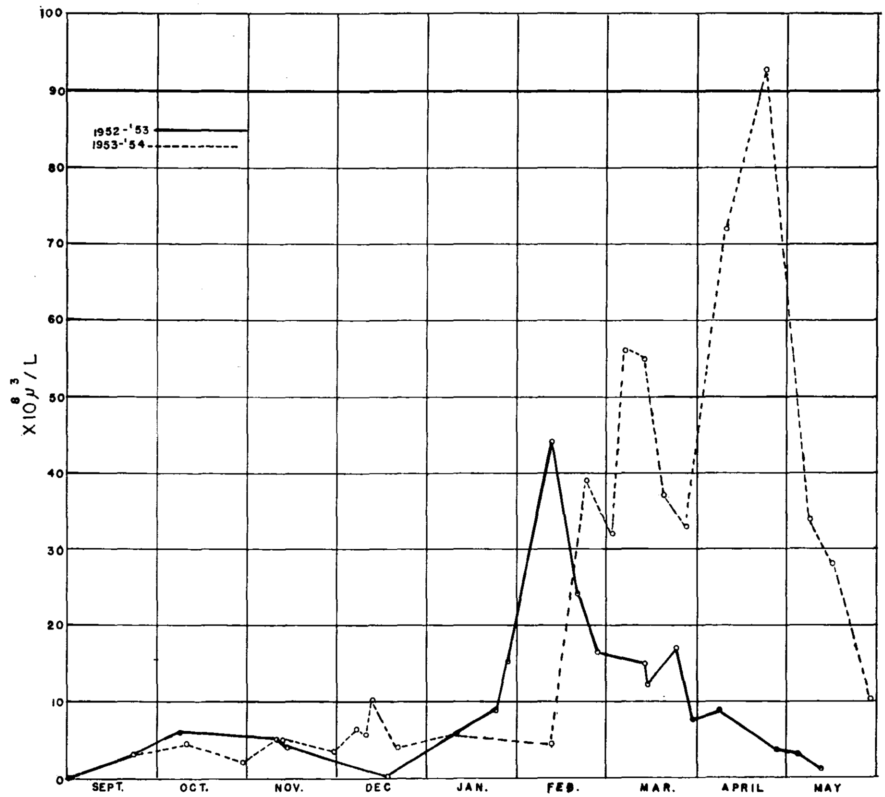

FIGURE 2. Graph showing phytoplankton populations in the fall, winter, and spring of 1952–54. Single station data.

while the data of Verduin, Curl, and the writer includes large populations of *Cyclotella melosiroides*. The appearance of this species corresponds with a drop in populations of *Stephanodiscus*. No records of *C. Melosiroides* were found prior to 1950. 3) Chandler reports his populations in maxima and minima; thus the maxima of comparable studies are given. It should also be borne in mind that Chandler's figures are from a single station. 4) Two species of *Tabellaria* are found abundantly in Western Lake Erie: *T. floculosa* and *T. fenestrata* var *asterionelloides*. Chandler found the former to make up the bulk of his *Tabellaria* populations. The writer, on the other hand, found the latter in greater numbers than did Chandler. In both studies the two species were combined for ease of computation.

Examination of table 1 shows a wide range of values. Conversion of Chandler's *Melosira* data was difficult because of great variations in cell size. A strand of *Melosira* 100 μ long varies from 2800 to 8000 μ^3. Examination of the month's data during which the maximum was reached indicates that the period in which the peak population of the individual species was reached has not radically changed. The *Melosira* peak appearing in December of 1953–54 may have been sub-maximal if samples had been taken in August and early September when *Melosira* is usually dominant.

Table 1 shows large variations in the maxima from year to year, and shows the conspicuous absence of *C. melosiroides* before 1950. The maxima of *Asterionella, Tabellaria*, and *C. melosiroides* occurred in spring, and the *Melosira* maxima usually occurred in the fall.

One objective of this study was to investigate possible correlations in variations in cell dimensions within certain species, with seasonal and horizontal distribution. Vegetative reproduction of diatoms involves formation of valves within the mother valve. These daughter valves produce new frustules, etc., throughout the vegetative growth period (Boyer, 1926). Because new frustules are formed within the elder a constant diminution should take place, at least in forms where expansion cannot take place. Such diminution is not true in some forms, however (Fritsch, 1935). Reduction is presumed gradual, therefore, until an auxospore is formed and an enlarged cell is produced. Diminution in size might theoretically continue indefinitely were there not formation of rejuvenescent cells of much larger size (Smith, 1933). Testing the hypothesis of cell diminution is difficult when whole populations are taken into consideration. Repeated auxospore formations would keep the cells from attaining the minimal size. Influx of new populations into the sampling area or sampling in different communities would also affect a curve of cell sizes.

An attempt was made in this study to determine whether diminution actually occurred among the major components of the diatom populations. The graduations of the ocular micrometer used in measuring were equal to 3.3 μ.

Average cell dimensions were tabulated for all of the major components, the dimension used being the diameter in those belonging to the Centrales (*Melosira* and *Cyclotella*) and the width in members of the Pennales (*Asterionella* and *Tabellaria*). That the other dimensions would be affected through vegetative reproduction is unlikely.

Two separate populations of *Melosira* were considered; one with a diameter of between 10 and 12 μ and one with a diameter between 5 and 7 μ. Examination of a curve of average diameters seems to indicate a decrease as the fall months progress and an increase from March through May. Apparently no diminution occurred at this time or if it did, it may have been offset by auxospore formation or by the influx of a new population. No auxospores were observed in the samples, however, and observation at other times seems to indicate auxospore formation during the summer months.

Cells of *Asterionella formosa* were found to have a fairly constant diameter throughout the year with variations between three and four micra. Samples taken at a single station during the period when ice cover made mobile sampling impossible did not indicate a significant trend in this dimension.

Widths of *Tabellaria* cells were found to differ by almost two micra over a period of three months, the median diameter being approximately 8.8 μ. Early spring measurements indicated a fairly rapid decline from 9.3 to 7.7 μ over a period of two weeks. If this decline was due to diminution through vegetative reproduction then the vegetative existence of the individual cells was short. A slight rise was indicated in April with another rapid drop in May.

Of the species studied, *Cyclotella* was found to have the greatest variation in cell diameter. A decline of from 10.6 to 7.9 μ in 14 days was observed. Though the magnitude is greater the time of decline paralleled that of *Tabellaria*. Because *Cyclotella* was found to be particularly abundant in the winter months of 1953, the diameters of cells collected at a single station during the winter and spring of 1953 and 1954 were averaged and graphed (fig. 3). The 1953 data show a slow increase of one micron during the winter and a decline from 12.5 to 7.9 μ over a period of over two months. Such slow decline might be considered due to vegetative reproduction. The 1954 data, on the other hand, show a gradual increase in cell dimensions. This increase in cell size was noted in the fraction of *Cyclotella* recovered with the millipore filter over this same period. The trend

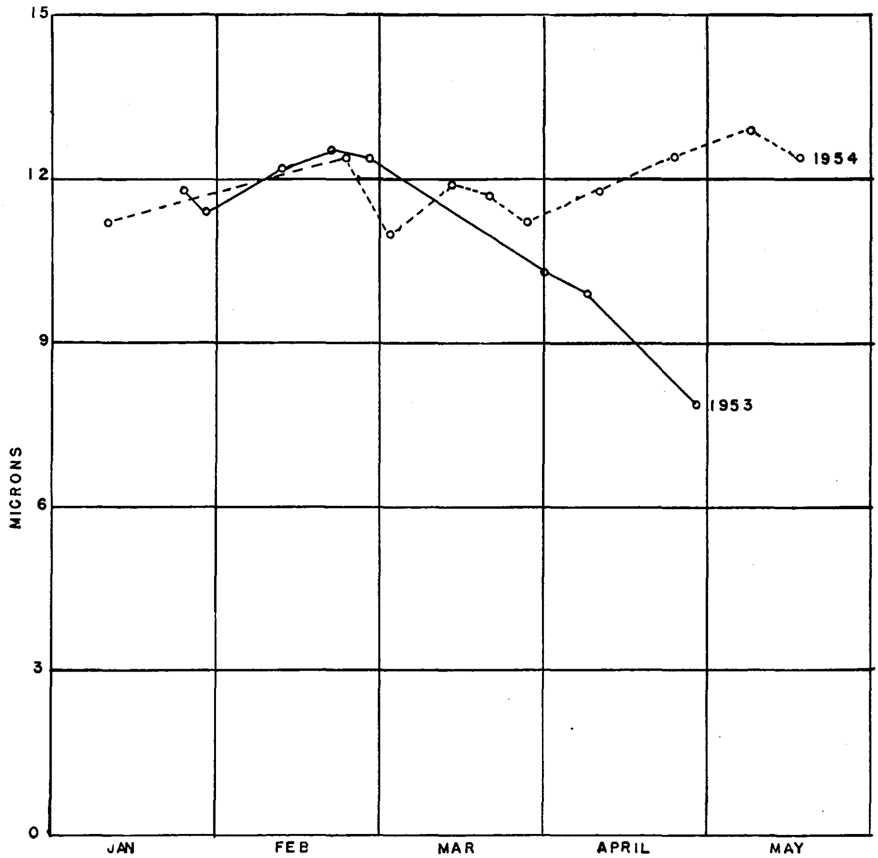

FIGURE 3. Average diameters of *Cyclotella melosiroides* graphed against time.

of cell dimension changes, therefore, were inconsistent and did not provide evidence supporting the theory of cell diminution during vegetative growth. The fact that auxospores were never observed in the collections makes it unlikely that repeated auxospore formation in the community obscured actual trends.

Studies of cell dimensions with reference to the horizontal distribution of the species showed no appreciable differences relative to position in the lake. Though the size of *Cyclotella* cells varied on the average by almost one micron in some areas, no significant trend of horizontal distribution was indicated. The dimensions of the other species usually did not vary by more than 0.4 μ.

SUMMARY

Phytoplankton studies showed average crops of 6 to 17 x 10^8 μ^3/1 during 1952–53 throughout the island region. Single station data during the same seasons in 1953–54 showed higher crops largely due to the introduction of a new filtering device, the M. F. millipore filter, which retained quantities of *Cyclotella melosiroides* that were lost by bolting cloth filters.

Single station data during the years 1952–53 indicated the peak of the population occurred in February while in 1953–54 two pulses occurred; one in March and one in April.

Melosira comprised more than 90 percent of the fall phytoplankton volume during the two fall periods studied.

A diatom unrecorded for Western Lake Erie prior to 1950, *Cyclotella melosiroides*, has become a major component of the phytoplankton populations. 75 to 95 percent of the phytoplankton volume in the winter and spring of 1954 was composed of *Cyclotella melosiroides*.

Graphs of variations in cell dimensions of certain diatoms show a variety of trends not consistent with the theory of gradual diminution of vegetative cell size and subsequent increase due to auxospore formation. *Asterionella formosa* was found to have a fairly constant cell width throughout the season in contrast to *Cyclotella melosiroides* which varied from approximately 7 to 14 μ.

ACKNOWLEDGEMENTS

This study was conducted at the Franz Theodore Stone Institute of Hydrobiology at Put-in-Bay, Ohio. The writer wishes to acknowledge the valuable aid given by Dr. Jacob Verduin, who served as adviser, and by Dr. Thomas H. Langlois, Director of the Institute.

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